CANADIAN
ENERGY
RESEARCH
INSTITUTE

3512 - 33 ST. N.W., Calgary, Alberta — T2L 2A6

Phone: (403) 282-1231

WORKING PAPER 84-2

AN ASSESSMENT OF BENEFITS AND COSTS OF USING METHANOL AS A MOTOR GASOLINE EXTENDER IN SOUTHERN ONTARIO

SEPTEMBER 1984

By

Walter Haessel
and
Tricia Gibson

Working papers are distributed by the Canadian Energy Research Institute in limited numbers. They represent the results of work in progress and are made available in this preliminary form both for information and to obtain comments.

TABLE OF CONTENTS

FIGURES iv

TABLES iii

ACKNOWLEDGEMENTS v

EXECUTIVE SUMMARY vii

CHAPTER 1 INTRODUCTION 1

1.1 Overview 1

1.2 Objectives 1

1.3 Study Outline 2

CHAPTER 2 METHANOL MARKETS 5

2.1 The Current Market Situation 5

2.2 The Market Outlook 7

2.3 Methanol as an Automotive Fuel 7

2.4 Methanol Blended as a Gasoline Extender 9

CHAPTER 3 SOCIAL BENEFIT COST ANALYSIS 13

3.1 Introduction 13

3.2 Description of the Project 14

3.3 The Social Benefits and Costs 15

3.4 Sensitivity Analyses 18

3.4.1 Social Discount Rates of 5 and 15 Percent 20
3.4.2 Higher Methanol Export Prices 20
3.4.3 Lower Oil Prices 20
3.4.4 Lower Butane Prices 20
3.4.5 Higher Feedstock Costs 21
3.4.6 Methanol Transport By Rail 21
3.4.7 Higher Cosolvent Costs 21
3.4.8 Methanol-to-Cosolvent Ratio 21

3.5 Non-Quantified Social Benefits and Costs 22

3.6 Conclusions and Qualifications 23

CHAPTER 4 A COMPARISON OF THE PRIVATE BENEFITS AND COSTS OF USING METHANOL AS A GASOLINE EXTENDER 25

4.1 Introduction 25

4.2 Calculation of Private Benefits and Costs 25

4.3 A Comparison of Private and Social Benefits and Costs 27

4.4 Problems of Implementation 29

CHAPTER 5 SUMMARY AND CONCLUSIONS 33

APPENDIX A ASSUMPTIONS FOR THE BENEFIT-COST ANALYSIS 35

A.1 Base Case Assumptions 37

A.2 Impact Case Descriptions 40

APPENDIX B DETAILED BASE CASE DATA TABLES 43

APPENDIX C SOCIAL BENEFIT-COST ANALYSIS SUMMARY OF RESULTS 53

APPENDIX D SUMMARY OF SELECTED METHANOL BLENDING TEST RESULTS 57

BIBLIOGRAPHY 61

FIGURES

2.1 Average U.S. Methanol and Natural Gas Prices: 1978-1983 ... 6

3.1 Net Present Value for Blending Methanol with Gasoline in Southern Ontario 19

4.1 Private and Social Benefits and Costs for Blending Methanol and Cosolvents with Gasoline 28

TABLES

2.1 Canadian Methanol Capacity, 1983 5

2.2 Major Methanol Projects Planned or Under Construction 8

3.1 Discounted Social Benefits and Costs of Blending Methanol as a Gasoline Extender in Southern Ontario 17

ACKNOWLEDGEMENTS

The Canadian Energy Research Institute has undertaken several studies in the area of alternative transportation fuels and research in this area is continuing. The current report has evolved significantly since its inception, largely as a consequence of discussions with key industry and government personnel and extensive reviews and comments on earlier reports on this project.

We would like to acknowledge the assistance of numerous individuals in the methanol industry, oil companies, chemical companies, governments and universities who provided us with data, information and advice and commented on earlier versions of the work. In particular, individuals in the Ontario Ministry of Energy; Alberta Energy and Natural Resources; Energy, Mines and Resources Canada; Celanese Canada Inc.; Alberta Gas Chemicals Ltd.; Norcen Energy Resources Ltd.; Dome Petroleum Ltd.; Shell Canada Resources Ltd.; Gulf Canada Ltd.; Petro-Canada; Imperial Oil Ltd.; and Novacor Chemicals Ltd. contributed in a significant way at various stages of the study and their inputs are greatly appreciated.

Thanks are also due to Len Coad for his assistance in programming and general analytical support. Finally the efficient typing of Jeannette Stinn and Janice Morrison are gratefully acknowledged.

Any remaining errors or omissions are the sole responsibilities of the authors.

EXECUTIVE SUMMARY

Methanol has been suggested as a substitute transportation fuel in Canada because:

(1) a worldwide surplus of methanol exists;

(2) Canadian methanol production capacity exceeds reasonable domestic requirements for the forseeable future; and

(3) blending low levels of methanol with gasoline and appropriate cosolvents is profitable with current and anticipated gasoline and methanol prices.

The study indicates that with the most likely set of assumptions, the benefits to society of blending equal amounts of methanol and cosolvent with gasoline exceed the costs by about 14 percent. After an initial implementation period, the ratio of methanol to cosolvent could be increased with substantial improvements in social profitability.

The private costs and benefits indicate that the value of blending low levels of oxygenate exceed costs indicating that the project is profitable. The savings would amount to a reduction of about 1 percent in the cost of the blended fuel.

A cost saving of this magnitude may be too low to induce refiners to incur the implementation costs and risks of starting a blending program. The analysis indicates blending will probably be commercially viable once it is in operation. Since the program is socially profitable but not commercially viable at the outset, a limited period of government assistance to help defray the initial costs of implementing an oxygenate blending program along the lines of that suggested by the Canadian Oxygenated Fuels Association would facilitate blending.

Chapter 1

INTRODUCTION

1.1 Overview

This paper reports on an economic assessment of the social and private benefits and costs of using methyl alcohol as a low percentage blend with gasoline. The technical merits of various alcohols as alternative transportation fuels have been well documented. The economics of their use, however, has not been explored to the same degree.

Preliminary results of this research were presented at the "VI International Symposium on Alcohol Fuels Technology,"[1] and at a seminar on "Methonal as an Automotive Fuel" organized by the Canadian Energy Research Institute.[2] An earlier version of the paper was widely circulated for comments. As a consequence of the discussions and comments on the earlier work, the assumptions, analysis and conclusions have evolved considerably.

Methanol is a logical choice as an alternative liquid fuel in Canada. A worldwide surplus of methanol exists and Canadian production capacity far exceeds foreseeable traditional Canadian requirements in this century. A combination of weakness in traditional markets, the addition of substantial capacity since 1978 and scheduled further additions in Mexico and the Middle East suggest that worldwide production capacity will exceed traditional requirements to the end of the decade and export markets for methanol will remain weak.

1.2 Objectives

The main objectives of the paper are:

- provide an overview of the methanol market and outlook; outlook;
- to review some technical aspects of methanol's use as an automotive fuel;

- to determine the social benefits and costs of integrating a low percentage of methanol into the Southern Ontario automotive fuel market; and
- to review the economic feasibility of the scheme from a private perspective.

1.3 Study Outline

A brief review of the current state of the methanol market followed by the market outlook is found in Chapter 2. The current supply/demand imbalance is expected to prevail unless methanol fuel markets develop. The main ways in which methanol can enter the automotive fuel market are outlined and the advantages and disadvantages of methanol relative to gasoline, from a technical perspective, are reviewed.

Using benefit-cost analysis as a tool, the social economics of using methanol as a fuel extender in Southern Ontario is investigated in Chapter 3. The methanol is assumed to be manufactured at an existing Alberta plant and is transported to Ontario via pipeline. It is blended with cosolvent, corrosion inhibitors and tailored gasoline at the refineries. Sensitivity tests are used to determine the responsiveness of results to changes in key variables such as methanol-to-cosolvent ratio, methanol transport costs, cosolvent costs and methanol export prices.

The scheme is evaluated from a private perspective in Chapter 4 and results are compared with the social benefit-cost analysis. A proposal by the Canadian Oxygenated Fuels Association for providing assistance to implement a blending program is briefly reviewed.

Summary and conclusions are found in the final chapter.

Footnotes

[1] The earlier version is printed in W. Haessel and T. Gibson "A Social Benefit-Cost Analysis of Using Methanol as a Motor Gasoline Extender in Southern Ortario, "VI International Symposium on Alcohol Fuels Technology Proceedings, Ottawa; May, 1984, Volume II, pp. 2-275 to 2-281.

[2] W. Haessel, "Results of Recent CERI Benefit/Cost Study: An Overview," presented at a Seminar organized by the Canadian Energy Research Institute, "Methanol as an Automotive Fuel," Edmonton, June 18, 1984.

Chapter 2

METHANOL MARKETS

2.1 The Current Market Situation

Worldwide methanol supply potential exceeded demand by over 4 million cubic meters or by around 26 percent in 1983. World methanol production capacity has increased by 40 percent since 1980.[1] A marked softening in prices has resulted with the average price dropping from around $152 (U.S.) per cubic metre in 1981 to the $108 to $127 (U.S.) per cubic metre range in 1983.

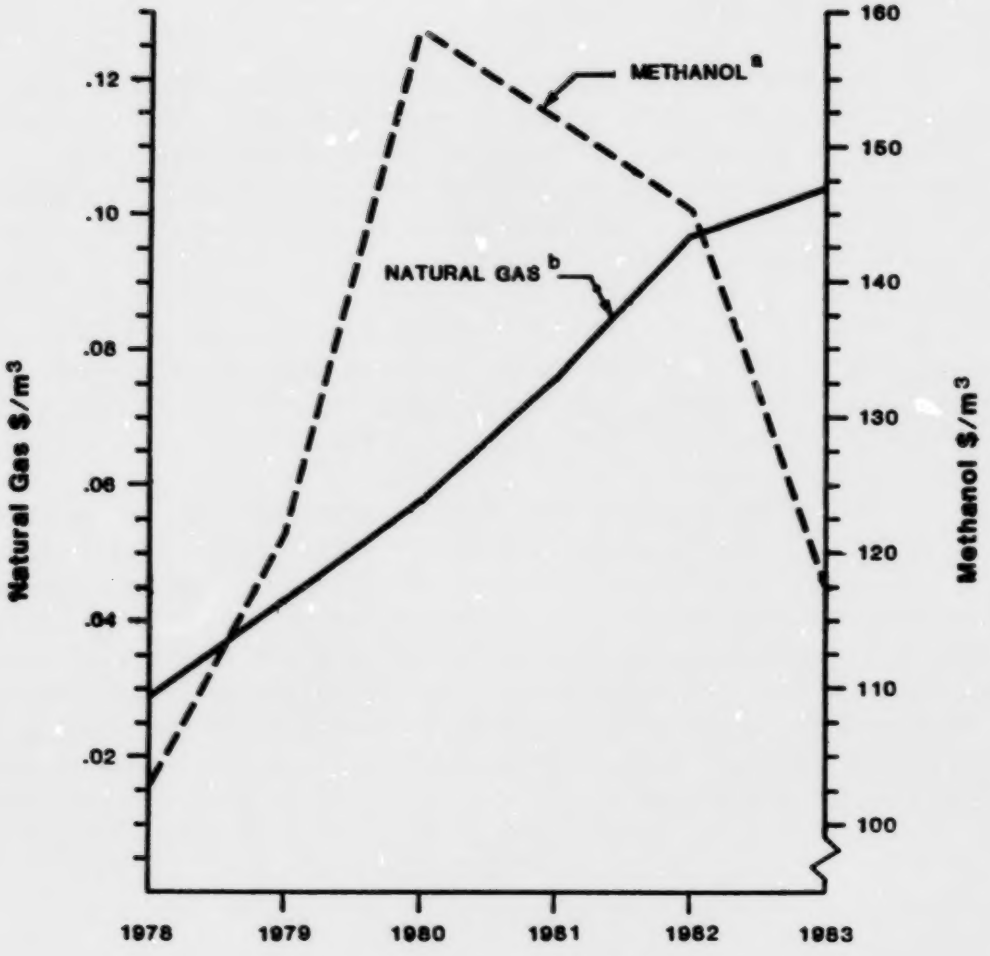
The historical positive relationship between methanol and natural gas prices has broken down, at least temporarily. Figure 2.1 shows that while natural gas prices continued to rise through 1983, methanol prices have been declining since 1980.

In Canada, capacity for methanol production is estimated to exceed domestic demand by over 1.9 million cubic metres. Total capacity is 2.3 million cubic metres compared to domestic demand of around 250 thousand cubic metres or less. Canadian production capacity amounts to about 17 percent of world capacity and consists of three plants as is illustrated in Table 2.1. A combination of weak traditional markets due to the general economic downturn and the start up of three major methanol projects in Canada in 1982 resulted in the present excess capacity situation.

TABLE 2.1

CANADIAN METHANOL CAPACITY, 1983

Company and Plant Site	Thousand Cubic Metres
Alberta Gas Chemicals Ltd. Medicine Hat, Alberta	907
Celanese Canada Inc. Clover Bar, Alberta	869
Ocelot Industries Ltd. Kitimat, British Columbia	504
TOTAL CAPACITY	2280



NOTE: a) Market prices.
b) Purchases from producers by major interstate pipeline companies.

SOURCE: Oil and Gas Journal, July 2, 1984, p. 62.
U.S. DOE/EIA Monthly Energy Review, January 1984, p. 93.

FIGURE 2.1: AVERAGE U.S. METHANOL AND NATURAL GAS PRICES: 1978-1983

2.2 The Market Outlook

Maximum expansion in methanol capacity up to 1990 can be determined from construction contracts that have been signed or are negotiated (see Table 2.2). The current methanol oversupply situation has resulted in postponement or cancellation of some projects (e.g., the Biewag plant in Alberta). The projects in Table 2.2 could add as much as 80 percent to existing world capacity by 1990 if all are implemented on schedule.

Chemical markets are expected to rebound from their currently depressed levels as the world economy picks up, but demand growth in traditional markets is unlikely to absorb existing and projected capacity additions in this decade.

Unless new markets for methanol are found, the supply/demand imbalance will persist. The most promising area for expanding methanol markets is through development of methanol fuel markets. Methanol could even come into short supply if North American motorists used methanol as a gasoline substitute or extender.

2.3 Methanol as an Automotive Fuel

Methanol can enter the automotive fuel market in four basic ways:

- as neat fuel (i.e., 90 to 100 percent methanol);
- as a blend with gasoline (up to 15 percent methanol);
- as a gasoline additive to increase octane rating; or
- converted to gasoline using Mobil Oil's process.

Two major obstacles will prevent penetration of neat fuel in the short run: the necessity for extensive engine redesign and the lack of an established neat fuel distribution system. In order to realize methanol's potential as a superior neat motor fuel, vehicle engines must be redesigned to allow for higher compression ratios. In addition, because of the corrosive nature of methanol, not only engine parts but some other vehicle parts must be replaced with methanol compatible materials. The cost of adapting vehicles for methanol fuel use along with the cost of establishing a methanol tolerant fuel distribution system will prohibit mass conversion to neat fuel in the short- to medium-term. Moreover, recent world oil price trends have

TABLE 2.2

MAJOR METHANOL PROJECTS PLANNED
OR UNDER CONSTRUCTION
(thousand cubic meters/year)

	1985	1990
U.S.		
Tennessee Eastman	227	
Peat Methanol		227
CANADA		
Biewag		2 082
Canadian Methanol Canadian		492
MEXICO		
Pemex	984	984
CENTRAL/SOUTH AMERICA		
Trinidad	492	
Wheelabrator-Frye Chile		946
NEW ZEALAND		
Petralyos Chem New Zealand	492	
GLICO New Zealand	908	908
ASIA		
Pertamina - Indonesia	492	
Malaysia		833
Burma	189	
India	76	
WESTERN EUROPE		
SIR - Italy	151	
Methanor Netherland		1 287
MIDDLE EAST/AFRICA		
Sabic/Celanese/Texas Eastern	871	
South Africa	492	492
GPCI Bahrain		416
Ra'sal Khaymah - U.A.E.	1 022	
EASTERN EUROPE		
East Germany	568	
USSR		1 022
Yugoslavia		265
TOTAL	6 965	9 956
CUMULATIVE	6 965	16 921

SOURCE: Based on S. Penny, "MTBE and GTBA Production from Butanes will Create New Methanol Market," a paper presented at the First International Conference on Fuel Methanol, New York, May 9-10, 1983.

temporarily suspended interest in fuel substitutes which require major initial capital investment.

Conversion of methanol to gasoline via the Mobil methanol-to-gasoline (MTG) process represents another option for utilizing methanol in the motor fuel market. The process is costly and is not considered to be economic in Canada at the present time.

The outlook for growth in methyl tertiary butyl ether (MTBE) markets is optimistic. As lead is phased out due to environmental concerns, MTBE will become more widely used as an octane enhancer. However, the quantity of methanol required as feedstock is small relative to the world surplus. Furthermore, the production of MTBE is likely to be limited by a shortage of isobutene for the foreseeable future.

2.4 Methanal Blended as a Gasoline Extender

Blending methanol with gasoline as a fuel extender appears to represent the best prospect for short-run increases in the use of methanol as a transportation fuel. Although problems may be encountered, these can largely be corrected within the present fuel system and without major costs being incurred. Furthermore, methanol gasoline blends have performed well in road tests using conventional automobiles. Even though methanol contains less energy per unit volume than conventional gasoline, road tests consistently indicate no significant difference between the distance driven per volume of fuel for low-level methanol blends to conventional gasoline.[2]

Phase separation, or the separation of methanol and gasoline into layers, occurs in the presence of water or at low temperatures resulting in the motorist experiencing stalling or starting problems.[3] Addition of higher alcohols and aromatics, such as isobutanol, isopropanol and tertiary butyl alcohol (TBA) improves the blend's tolerance to water and cold temperature. However, these cosolvents are expensive and in limited supply. Corrosion, the other major potential problem, can be eliminated by the addition of appropriate corrosion inhibitors. These problems are minimized when methanol is blended in low percentages (i.e., 5 percent or less) with gasoline.

The remainder of this paper is devoted to examining the economics of a scheme to designate a portion of the output of an existing Alberta methanol plant for use as a motor gasoline extender in Southern Ontario.

Footnotes

[1]See a paper by J. K. Lambie, "Developments in Methanol and its Derivatives and Their Impact on the Western Canadian Natural Gas Industry." Presented to the Canadian Gas Processors Association, Calgary, September 12, 1984.

[2]The results of selected road tests are reviewed in Appendix D.

[3]Water could be present in the fuel storage tank or in the distribution system. It has been suggested that blending at the refinery, as opposed to blending at the pumps, would ensure tighter control and less chance of contaminating a "dry" system with problem-causing water. This would be the case in Canada where large integrated oil companies control both the refining and retail phases. It would be more difficult for U.S. refiners to monitor movement of their output since the product changes hands several times prior to reaching the final destination.

Chapter 3

SOCIAL BENEFIT COST ANALYSIS

3.1 Introduction

Benefit-cost analysis is a method of consistently calculating and comparing the benefits and costs of implementing a particular project. All benefits and costs incurred throughout the life of the project are estimated and the present values of future costs and benefits are computed using a discount rate as:

$$B = \sum_{t=0}^{T} B_t/(1+r)^t, \qquad (1)$$

and

$$C = \sum_{t=0}^{T} C_t/(1+r)^t, \qquad (2)$$

where

B_t = benefits in year t ,
C_t = costs in year t ,
r = discount rate, and
T = life of the project in years.

Finally the discounted costs and benefits are compared. The amount by which discounted benefits exceed costs is known as the net present value of the project. A useful summary statistic is the ratio of benefits to costs. A project is considered desirable if this ratio exceeds one.

In this chapter, benefits and costs are valued from society's standpoint. All resources employed on the project are valued at their social opportunity cost which is their worth to society in their next best alternative use. The benefits of the project are appraised by valuing the project's outputs at their worth to society. Social costs and benefits differ from private costs and benefits (market prices) in two important ways. First, market prices must be adjusted to remove

taxes and subsidies since taxes and subsidies are merely redistributions of purchasing power among segments of society rather than costs and benefits to society. Second, the value of resources (inputs or outputs) may differ from market prices due to market imperfections of various kinds.

A classic example of a market imperfection is the fact that product prices often differ from the social cost or value of producing or consuming a product. For example, methanol motor fuel pollutes less than gasoline, a social benefit that theoretically should be quantified and result in a higher social value for methanol as a motor fuel than for gasoline. However, in a free market individual consumers will not be willing to pay more for methanol than gasoline since the lower pollution value of methanol benefits society as a whole and not just the purchaser. The distortion between private and social value of methanol as a fuel relative to gasoline could be removed by subsidizing methanol consumption or taxing gasoline consumption.

3.2 Description of the Project

The project evaluated involves blending a low level of methanol with tailored gasoline sold in Southern Ontario for the period 1983 to 2002. The methanol is assumed to be manufactured at the Celanese Canada plant at Clover Bar, Alberta, and is transported to Ontario via Interprovincial Pipeline Ltd. The blending occurs at Ontario refineries and all refineries except Petrosar are assumed to blend. Petrosar is excluded since its output is primarily chemical feedstock.

The base case assumes a one-to-one methanol-to-cosolvent ratio of 5 percent methanol and 5 percent cosolvent. Methanol, cosolvent and appropriate corrosion inhibitors are added to 90 percent gasoline tailored to meet Canadian Gasoline Standards Board specifications.

The goal is to ultimately utilize a two-to-one methanol to cosolvent ratio which would reduce costs considerably since the cosolvent is more expensive than the methanol. However, a one-to-one ratio would be desirable for an initial introductory period. A one-to-one ratio is less likely to cause problems due to water which may be in the distribution system. A two-to-one blend can be introduced after the one-to-one blend has been used for some time and the distribution system has been cleaned out.

Cosolvent is obtained from domestic sources. Requirements in excess of domestic supplies are imported from the U.S. until sufficient domestic cosolvent capacity is added to displace imports in 1988. All of the corrosion inhibitor is imported.

Some of the methanol is obtained by increasing the operating rate of the three Canadian plants to full capacity. Once full capacity is reached additional methanol required for blending is acquired by diverting exports from the U.S. Gulf Coast. Methanol is assumed to be swapped among their respective markets.

The addition of oxygenate (methanol plus cosolvent and additives) to gasoline is assumed to reduce imported crude oil requirements. The quantity of crude oil displaced is determined by the amount of oxygenate added minus the amount of butane which must be backed out of the gasoline stock to maintain acceptable vapour pressure levels in the blended fuel. The butane saved is credited to the project.

World oil prices in constant dollars are assumed to remain relatively flat to around 1990 and then increase about one percent per annum to the end of the period.

Natural gas feedstock prices are discounted from the Alberta Border Price to reflect the surplus of gas available and account for royalties and taxes. Methanol export prices are assumed to remain flat in nominal terms in 1983 and 1984, remain constant in real terms to 1990, and increase by 1 percent per annum in real terms thereafter. Butane prices escalate at the same rate as world oil prices and are kept at 85 percent of crude oil prices.

Additional details on the assumptions are specified in Appendix A. The actual data utilized are presented in Appendix B.

3.3 The Social Benefits and Costs

The social benefits of blending methanol into the automotive fuel market as a gasoline extender include the displacement of imported crude oil (or permitting extra oil exports), cost savings resulting from reduced refinery throughput, the net octane improvement resulting from the addition of the oxygenate which has a higher octane rating than regular unleaded gasoline, and the additional butane made available due to blending. The benefits to Canada are reduced by two

types of leakages; imports of cosolvents and corrosion inhibitors, and lower export revenues due to reduced methanol exports.

The social costs incurred by implementing the project include the feedstock and operating costs for the incremental methanol production, the pipeline costs for transporting the methanol to Ontario, additional tanks at the refinery for methanol and cosolvent storage, and domestic purchases of cosolvents. Transportation cost savings result from lower levels of methanol exports.

The discounted net social benefits and costs for the base case are summarized in Table 3.1 using a 10 percent real social discount rate. Under the set of assumptions outlined, the present value of net social benefits totals $929 million and exceeds net social costs of $814 million for a net present value of $115 million. Benefits exceed costs by about 14 percent resulting in a benefit-cost ratio of 1.14.

The discounted present value of crude oil savings is $416 million and represents the largest single component among the various benefits. Another $45 million is contributed by cost savings from reduced refinery throughput. Displaced butane is valued at $398 million.

The net octane credit from the higher octane value of oxygenate relative to gasoline adds $150 million to benefits. Imports of corrosion inhibitors and cosolvent reduce benefits by $39 million. Benefits are further reduced by $41 million lost export revenue because methanol is diverted from the export market.

The cost of domestic cosolvents amounts to $704 million; by far the largest cost category. Feedstock and operating costs for incremental methanol production are $70 and $25 million, respectively. These figures are relatively small because the natural gas feedstock costs do not include any taxes or royalties. Costs for transporting methanol by pipeline to Southern Ontario partly offset the cost savings that occur because less methanol is transported by rail to Vancouver for export. The cost of additional refinery storage and handling facilities for methanol and cosolvents is only $4 million.

In summary, initiating a project to blend Alberta methanol with gasoline in Southern Ontario appears to be socially desirable given the assessment of costs and benefits included in the base case. The net

TABLE 3.1

DISCOUNTED SOCIAL BENEFITS AND COSTS OF BLENDING METHANOL AS A GASOLINE EXTENDER IN SOUTHERN ONTARIO

Benefits and Costs	Millions 1983 $Cdn.
Social Benefits	
Displaced Imported Crude Oil	416
Reduced Refinery Throughput	45
Net Octane Credit	150
Butane Savings	398
Increased Imports	(39)
Reduced Methanol Export Revenue	(41)
Net Social Benefits	929
Social Costs	
Incremental Feedstock	70
Incremental Operating	25
Pipeline Transport	21
Domestic Cosolvent	704
Storage Tanks	4
Transportation Saving, Reduced Exports	(10)
Net Social Costs	814
Net Present Value	115

present value of the project is estimated to be $115 million and the benefit-cost ratio is 1.14.

3.4 Sensitivity Analyses

The data and assumptions used in the analysis have been widely discussed with key industry and government personnel. In many cases, the reviewers and commentators have not agreed among themselves. Consequently the significance of some of the more crucial and controversial assumptions have been tested using sensitivity analysis.

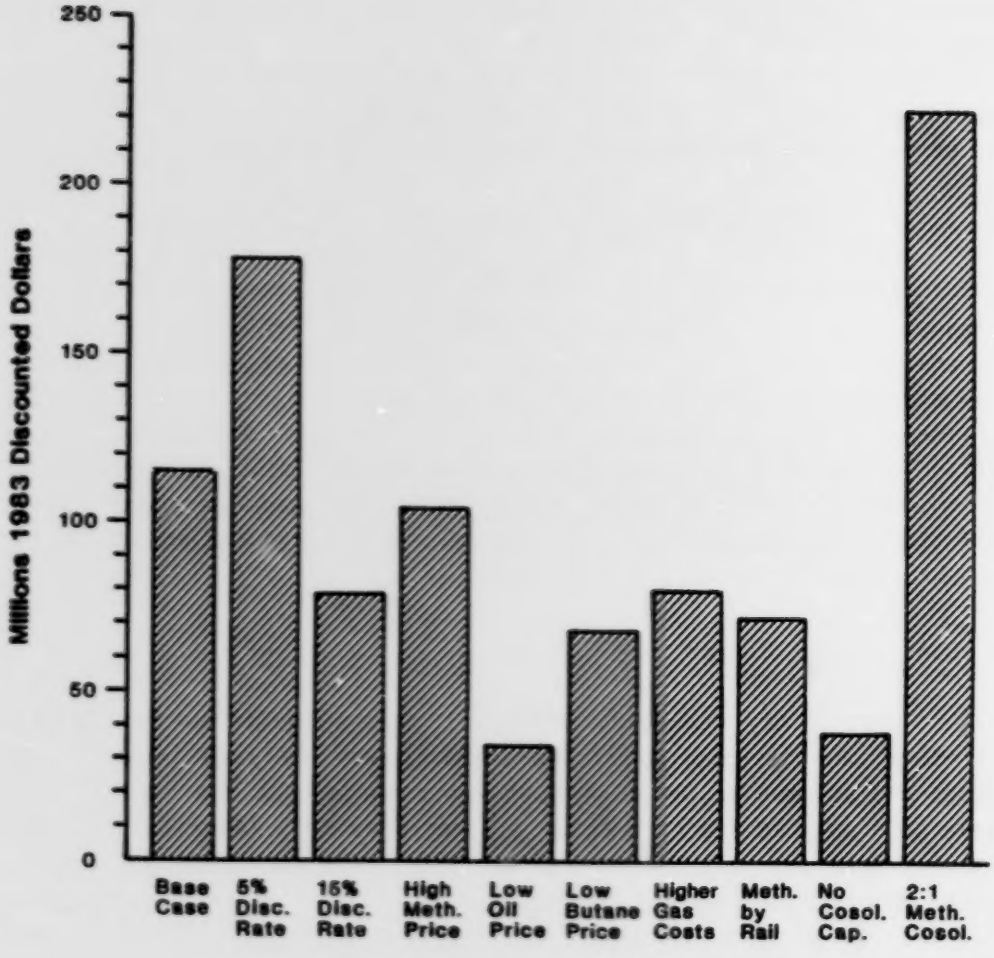
The nine sensitivity analyses reported include:

- discount rates of 5 and 15 percent;
- higher methanol export prices;
- methanol transportation by rail;
- no increase in domestic cosolvent capacity;
- a two-to-one methanol-to-consolvent ratio;
- lower world oil prices;
- lower butane prices; and
- higher natural gas feedstock costs.

The assumptions being investigated were changed one at a time with all other assumptions remaining unchanged from the base case. The assumptions are discussed in detail in Section A.2 of Appendix A.

The net present values for the nine scenarios are depicted in Figure 3.1, along with results for the base case. Detailed results are presented in Appendix Table C.1.

Figure 3.1 suggests that the estimated net present value of the project is extremely sensitive to the assumptions. The net present value ranges from a low of $36 million when 10 percent crude oil prices are assumed to a high of $233 when a two-to-one methanol-to-cosolvent ratio is assumed. Aside from the discount rate changes and the two-to-one blend, all of the scenarios examined were selected to be less favorable to the project. In spite of this, the net present value remained positive in every case. Each of the scenarios is discussed below.



SOURCE: Table C.1

FIGURE 3.1: NET PRESENT VALUE FOR BLENDING METHANOL WITH GASOLINE IN SOUTHERN ONTARIO

3.4.1 Social Discount Rates of 5 and 15 Percent

Varying the social discount rate to 5 and 15 percent from 10 percent has no impact on the conclusion. The net present value of the project changes to $178 and $79 million, respectively, and the benefit-cost ratio remains unchanged at 1.14 in all three cases. The conclusion is insensitive to varying the discount rate because the operating costs are very large relative to the up-front capital costs, and benefits and operating costs both increase over time.

3.4.2 Higher Methanol Export Prices

The foregone foreign exchange earnings resulting from diverting methanol exports to the domestic fuel markets is treated as a reduction of benefits. If the methanol market is assumed to recover more quickly than assumed in the base case, foregone export earnings increase to $51 million and the net present value of the project decreases to $104 million. The impact is relatively minor because most of the methanol is obtained from increased domestic production, and the major export price increases occur after 1990 and thus have a reduced impact on the present value.

3.4.3 Lower Oil Prices

Uncertainty regarding world oil prices continues to prevail. Therefore, an alternative pricing scenario was analyzed in which oil prices are assumed to be 10 percent lower throughout the period. The value of displaced imported crude oil declines to $374 million. Since butane prices and natural gas feedstock costs are tied to oil prices, butane savings and the cost of feedstock for incremental production also decline although the impact on feedstock costs is negligible. The net present value of the project declines to $36 million.

3.4.4 Lower Butane Prices

One of the largest components in the benefits is the butane saving. When butane prices are set equal to 75 percent of crude oil prices butane savings decrease to $351 million. Under this set of assumptions, the net present value of the project is $68 million.

3.4.5 Higher Feedstock Costs

Great uncertainty exists about the future direction of natural gas prices. The base case assumes that the methanol is produced with natural gas feedstock discounted substantially from the Alberta border price in the early years, with the gap narrowing during the 1990s and being eliminated by the end of the period. (Royalties and taxes have been deducted from the price.) An alternative scenario assumes prices are 50 percent higher throughout the entire period, and the net present of the project declines to $80 million.

3.4.6 Methanol Transport by Rail

The base case assumes that methanol is shipped from Edmonton to Sarnia via Interprovincial Pipeline. Since experience with shipping methanol by pipeline is limited, an alternative scenario considered the possibility of shipping methanol by unit trains. Shipping costs would be over three times the level in the base case, but the project would still have a net present value of $72 million.

3.4.7 Higher Cosolvent Costs

Cosolvent costs enter into the analysis in two ways; through imports and as a direct cost. The base case assumes that domestic cosolvent capacity will be expanded when a domestic market develops. A new plant is assumed to be phased in during the 1986 to 1988 period at which point cosolvent imports drop to zero. An impact scenario examined the implication of not developing domestic capacity. The net result is that import requirements increase from $39 million to $547 million, offset in part by a reduction in domestic cosolvent costs. The project net present value is reduced to $38 million.

3.4.8 Methanol-to-Cosolvent Ratio

Uncertainty surrounds the question of an acceptable methanol-to-cosolvent ratio. Limited existing experience suggests that, under most circumstances, a blended fuel with a one-to-one methanol-to-cosolvent ratio would avert any performance problems which could subsequently result in consumer complaints. Higher methanol-to-cosolvent ratios are desirable since methanol is less expensive than cosolvents. It is anticipated that the two-to-one ratio made up of 5 percent methanol and 2.5 percent cosolvent would perform satisfactorily

in the Southern Ontario market, and the profitability of such a blend was examined.

The net present value of the project nearly doubles to $223 million. Domestic cosolvent costs decline from $704 million to $368 million. This saving is offset to some extent because less crude oil is saved.

3.5 Non-Quantified Social Benefits and Costs

Certain benefits and costs have not been included in the analysis but would be incurred by society if the project was implemented. Some of the most significant of these benefits and costs are briefly discussed in this section.

One of the major benefits that would occur is increased energy self-sufficiency and security of supply. Using methanol as a gasoline extender would reduce the amount of crude oil consumed and reduce Canada's dependence on the world oil market.

Natural gas is currently in excess supply in Canada. Diversifying and increasing the demand for methanol would help create a market for shut-in natural gas.

Use of methanol fuel effects an improvement in the environment from reduced motor vehicle emissions of sulfur and nitrogen oxides. On the other hand, aldehyde emissions would be increased.

Blending methanol with gasoline would create a market for cosolvents in Canada. Chemical companies have expressed interest in building a cosolvent plant if a Canadian market develops. The construction and operation of a cosolvent plant would create jobs and generate income.

One adverse effect that has not been quantified is that less refinery throughput would be required if the project is implemented. Thus, some refinery capacity would be idled in an industry where there is already excess capacity. However, this would be partly offset by increased utilization rates for existing methanol plants. It is unclear what the net effect of these two forces would be.

The element of risk has not been included in this analysis. It is a significant concern, however, and its omission means project costs are probably understated.

3.6 Conclusions and Qualifications

Blending low levels of methanol and cosolvent with gasoline in Southern Ontario appears to be socially profitable. The base case indicates a net present value of $115 million (1983 dollars) and net benefits exceed net costs by about 14 percent. Sensitivity analysis has been used to investigate the implications of more pessimistic assumptions for some of the more crucial variables. In each of the cases considered the project is still profitable.

The base case assumes a one-to-one ratio of methanol to cosolvent because the higher cosolvent proportion is likely to result in fewer problems as the blend is being introduced. However, once blended fuel is widely used and the distribution system has been dried out, a two-to-one ratio would likely be acceptable, and a two-to-one blend is considerably more profitable than the one-to-one.

Chapter 4

A COMPARISON OF THE PRIVATE BENEFITS AND COSTS OF USING METHANOL AS A GASOLINE EXTENDER

4.1 Introduction

This chapter compares the private benefits and costs of blending methanol and cosolvents into the Southern Ontario automotive fuel market. The private analysis is less comprehensive than the social benefit-cost evaluation reported in the preceding chapter. The analysis is conducted from the perspective of an Ontario refiner deciding whether it is profitable to use methanol and cosolvent as a gasoline extender. The cost of one cubic metre of oxygenate is compared to its value to the refiner as a gasoline extender.

The analysis does not include any start-up costs other than storage tank requirements for methanol and cosolvent at the refinery. Thus, the initial costs of promotion of the blend and labelling of pumps, and costs associated with drying out the system[1] are not included. The actual costs and benefits will vary substantially among refiners depending on the configuration of the refinery capital stock.

Assumptions regarding world oil prices, methanol prices cosolvent costs, etc., are identical to those used in the social benefit-cost analysis with one exception. The methanol is assumed to be shipped from Edmonton to Ontario by rail and the costs are adjusted accordingly. Furthermore, prices and costs have not been adjusted for taxes and subsidies in the private analysis. Results are reported on an annual basis in 1983 undiscounted dollars.

4.2 Calculation of Private Benefits and Costs

Private benefits include displacement of one cubic metre of gasoline and the net octane improvement which results from the addition of a cubic metre of the oxygenate. Benefits are reduced by the value of the butane which must be backed out of the gasoline stock in order to maintain acceptable vapour pressure levels in the blended fuel. Gasoline and butane prices are assumed to escalate at the same rate as world oil prices.

Gasoline prices are taken at the refinery gate and are net of federal taxes since those taxes would have to be paid on both the gasoline and the oxygenate and would just cancel out in the analysis. However, the provincial fuel tax is included in the cost of the displaced gasoline to reflect the Ontario government's waiver of fuel taxes on non-petroleum based fuels.

The private costs incurred by the refiner include the cost of acquiring methanol and cosolvents. The methanol costs are calculated on the basis of diverted methanol exports transported to Ontario by rail.

Shown algebraically, the calculations of private benefits and costs per cubic metre of oxygenate are:

$$B_t = P_{gt} + NOC_t - b\left(P_{gt} - P_{bt}\right) \quad ; (1)$$

and

$$C_t = m\,P_{mt} + T_t + (1-m)\,P_{ct}\;C_{it} + C_{st} \quad ; (2)$$

where B_t = private benefits in year t ;
P_{gt} = price per cubic metre of regular unleaded gasoline at the refinery gate in year t (net of federal but including provincial fuel taxes);
NOC_t = net octane credit in year t ;
b = butane back-out factor per cubic metre of oxygenate;
P_{bt} = price of butane in year t ;
C_t = private costs in year t ;
m = share of methanol in oxygenate;
P_{mt} = producer netback per cubic metre at plant gate derived from methanol exports in year t ;
T_t = cost of shipping methanol from the plant to refinery in year t ;
$(1-m)$ = share of cosolvent in oxygenate;
P_{ct} = average delivered cost of cosolvent in year t ;
C_{it} = cost of corrosion inhibitors per unit of oxygenate in year t ; and
C_{st} = cost of storage facilities per unit of oxygenate in year t .

4.3 A Comparison of Private and Social Benefits and Costs

The annual private benefits and costs for the base case are shown in Figure 4.1(a). Benefits and costs are in 1983 undiscounted dollars per cubic metre of oxygenate.

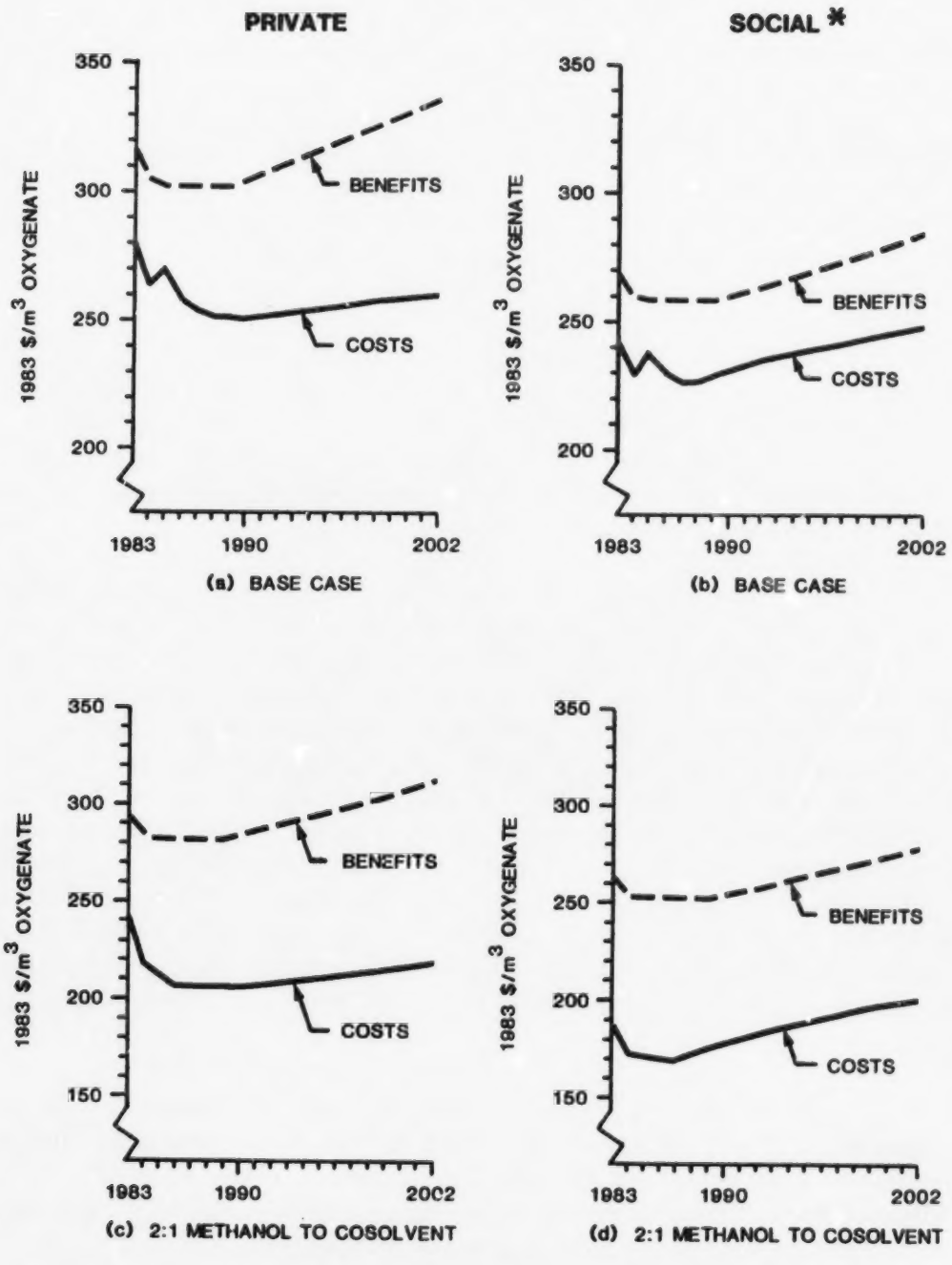
Benefits decline in 1984 and 1985 because the real price of gasoline is assumed to decline in those years, then remains flat to 1989 before escalating in the later years as world oil prices increase. Costs per cubic metre generally decline from 1983 to 1990 before escalating thereafter due to higher methanol prices.

Costs decline in the early years primarily because the cost of methanol and cosolvent storage facilities per unit of oxygenate declines.[2] Costs increase after 1990 because methanol prices are assumed to increase. The cost increase in 1985 results from a substantial quantity of cosolvent being imported in that year before domestic capacity is expanded in 1986.

Social benefits and costs per cubic metre of oxygenate added are shown for the base case in Figure 4.1(b). The social benefits and costs exhibit the same pattern over time as private benefits and costs, but the absolute level of private benefits and costs are higher than the social benefits and costs. Private benefits are higher than social benefits because the private value of displaced gasoline includes provincial taxes which are waived for alternate fuels in Ontario. Private costs exceed social costs for two reasons. First, the private cost of methanol is taken to be the cost of diverting methanol from the export market rather than allowing for incremental production from excess capacity. Second, the methanol is assumed to be shipped from Edmonton to Ontario by unit train rather than pipeline because pipeline shipments would probably be uneconomic if only one refiner were to blend.

Private benefits exceed costs by $36 per cubic metre of oxygenate in the first year, and this differential gradually widens throughout the period and exceeds $70 per cubic metre by 2002. This indicates that if all costs and benefits have been accurately captured, the project is profitable from a private perspective.

Annual private and social benefits and costs for the two-to-one case are shown in Figures 4.1(c) and (d). These costs and benefits



* NOTE: To aid in the illustrative comparison with the private analysis, imports and lost export revenue are assigned as social costs rather than foregone benefits.

FIGURE 4.1: PRIVATE AND SOCIAL BENEFITS AND COSTS FOR BLENDING METHANOL AND COSOLVENTS WITH GASOLINE

show the same basic relationships as for the base case. However, the margin by which benefits exceed costs is much larger in the two-to-one case, primarily because one-third less cosolvent is required and the cosolvent is relatively expensive. Private benefits are estimated to exceed private costs by $52 per cubic metre in 1983 and this differential widens to exceed $90 by the end of the project.

4.4 Problems of Implementation

No allowance has been made for any costs that refiners would incur to implement the program other than the cost of storage facilities for methanol and cosolvent at the refineries. Other costs include advertising and consumer education, pump labelling, drying out the distribution system and any capital costs which would have to be incurred to produce a lower portion of gasoline in the refinery product slate.

The actual costs and benefits of blending will vary substantially from one refinery to the next. The technical specifications of the refinery, the cost of alternative incremental octane per litre, the quality of the crude oil refined, and the product slate produced will all have a bearing on the costs and benefits.

A very serious problem from the refiner's standpoint is that they would have to handle a fourth stream of gasoline. Most refiners now manufacture leaded regular, unleaded regular, and unleaded premium gasoline, and each of these must be handled separately. If blended fuel is introduced as a fourth stream, handling and distribution costs will be increased substantially. This problem will be alleviated as leaded gasoline is phased out.

The blending of methanol and cosolvent in the base case will save the refiner about $36 per cubic metre of oxygenate at the outset and this will widen to over $70 per cubic metre by the end of the project. To put these figures into perspective, the $36 saving amounts to about a 1 percent reduction in the cost of blended fuel at the pump relative to regular gasoline. Implementing a two-to-one blend will amount to a savings of about 1.5 percent at the outset. These savings are unlikely to be a sufficient incentive for refiners to undertake the expenditures, problems and risks involved in implementing such a project.

The Canadian Oxygenated Fuels Association (COFA) is proposing a strategy of using a one-to-one methanol-to-cosolvent blend until such time that the system is dried out, the product has been proven, and the consumers have become educated. The strategy involves moving to a higher methanol-to-cosolvent ratio after the initial breaking-in period. The COFA strategy also includes a proposal for government assistance of 1¢ per litre of oxygenated fuel.[4]

For a blend involving 10 percent oxygenate and 90 percent gasoline, the COFA proposal would amount to a cost reduction of $100 per cubic metre of oxygenate. The government assistance combined with the cost savings from using the oxygenate itself would amount to a savings of nearly 4 percent on the blended fuel in the first year. If a two-to-one ratio can be attained by 1990, the estimated savings would amount to over 2 percent of the cost of the blended fuel. A savings of this magnitude should be sufficient to encourage refiners to blend after the problems and costs of project implementation have been incurred.

Savings of 4 percent of the cost of the fuel should be sufficient to encourage at least some refiners in blending oxygenate. The extent of interest will vary among refiners and the product slate produced by those refiners relative to the product slate demanded by the refiner's customers.

Footnotes

[1]Water mixes very readily with methanol. Thus, it is important that all tanks involved in the distribution system including tanker trucks and service station storage tanks be free of water. It may be necessary to clean some or all of these tanks to remove water.

[2]The cost of storage tanks is assumed to be expensed in the year of purchase rather than capitalized and depreciated over time.

[3]In the social cost-benefit analysis in Chapter 3, imports and foregone export earnings were treated as reductions in benefits. These two items are deleted from benefits and included as costs to facilitate comparisons with the private analysis in the current chapter. Thus social benefits per cubic metre of oxygenate include the crude oil savings plus savings for the reduced refinery throughput plus the butane backed out. Costs include domestic and imported cosolvent, corrosion inhibitor, natural gas and plant operating costs for incremental methanol production, methanol transportation to Ontario, foregone export earnings, and storage facilities. Costs are reduced by transportation savings on exports which are diverted to the fuel market.

[4]This strategy is discussed in a paper by the Canadian Oxygenated Fuels Association, "Methanol as a Transportation Fuel," presented at a Canadian Energy Research Institute Seminar, Edmonton, June 18, 1984.

Chapter 5

SUMMARY AND CONCLUSIONS

The social profitability of blending low levels of methanol produced in Alberta with gasoline in the Southern Ontario market has been assessed using benefit-cost analysis. The discounted net social benefits exceed net social costs by 115 million 1983 dollars resulting in a benefit-cost ratio of 1.14 for the base case assumption. This indicates the project is socially desirable for the most likely set of assumptions.

A number of more pessimistic assumptions were examined for their effect on the social profitability of the project. In every case considered, the net social benefits exceeded the costs indicating the project would be desirable for the scenarios postulated. Cosolvent costs and crude oil prices appear to be the most crucial variables.

The base case considered a one-to-one methanol-to-cosolvent blend involving 5 percent each of methanol and cosolvent. A one-to-one blend is most likely to be used initially to introduce oxygenate into the fuel distribution system. Once the implementation problems have been surmounted and the product has been proven, it should be possible to switch to a more profitable blend involving a higher methanol/cosolvent ratio. The two-to-one blend evaluated had a net present value of $223 million; nearly double that of the base case. The benefit/cost ratio is 1.47, indicating net social benefits exceeded net social costs by nearly 50 percent.

A comparison of private benefits and costs of the project under the most likely set of assumptions indicates that blending of methanol and cosolvents with gasoline is profitable from the refiners' standpoint. The value of adding oxygenate is estimated to exceed the costs of the oxygenate by about $36 per cubic metre in the first year with the differential widening to over $70 per cubic metre by the end of the project. This amounts to about a 1 percent reduction in the cost of the blended fuel. If a two-to-one blend is introduced, the cost savings amount to about 1.5 percent of the blended fuel costs. Savings of this magnitude are unlikely to encourage refiners to undertake the costs and risks of implementing a program of oxygenate blending.

The Canadian Oxygenated Fuels Association (COFA) has proposed a program to implement blending of equal shares of methanol and cosolvent and then switching a higher methanol/cosolvent ratio. The COFA proposal suggests government assistance for a limited period of 1¢ per litre for blended fuel to help defray the costs of implementation. The short-term government subsidy implied by this program is a transfer of benefits from public to private sectors. The benefit cost ratio would not change as a result of the transfer. A 1¢ per litre subsidy is small relative to the federal and provincial taxes on gasoline.

The proposed government assistance plus the savings inherent in using the oxygenate suggest a blended fuel cost reduction of nearly 4 percent would result in the first year for a one-to-one blend. Savings in later years would be higher. Savings of this magnitude should be sufficient to encourage some refiners to blend fuels. The extent of interest will vary among refiners depending on the technical specifications of their refineries.

In conclusion, the results of this study indicate that the blending of methanol and cosolvent as a gasoline extender in Southern Ontario is socially desirable. On the other hand, the data suggest that the project is not sufficiently attractive from the private perspective to induce refiners to implement a blending program without some form of government assistance. The COFA proposal of assistance for a limited period of time to help defray the implementation costs would facilitate implementation. The assistance program could be phased out over time since the analysis suggests the project is commercially viable once the costs of implementation have been defrayed.

APPENDIX A

ASSUMPTIONS FOR THE BENEFIT-COST ANALYSIS

Appendix A

ASSUMPTIONS FOR THE BENEFIT-COST ANALYSIS

A.1 Base Case Assumptions

Key assumptions employed for the base case are discussed below.

1. Initially, the blended fuel (i.e., methanol, cosolvent and gasoline) penetrates 40 percent of the unleaded gasoline market in Southern Ontario. Penetration increases to 100 percent by 1986 and holds through the rest of the period. The volumes are based on total retail sales of motor gasoline in Ontario being held at 1982 consumption levels, with Southern Ontario representing 75 percent of the provincial market. Sales of unleaded motor fuel in Southern Ontario increase from 40 percent of retail sales of gasoline in 1983 to 90 percent in 1993, where they hold through the remainder of the period.

2. Methanol is produced at an existing natural gas fed Alberta plant located near Edmonton. It is assumed there is adequate surplus methanol capacity in Western Canada to produce an additional 200,000 cubic metres per year of methanol and that producers will reallocate markets to provide all the methanol for blending from the Edmonton plant.

3. Real world oil prices decline 4 percent in 1984, remain flat to 1989, thereafter increasing at about 1 percent per annum to the end of the period.

4. The natural gas feedstock cost for incremental production is projected as follows: The 1983 cost of natural gas feedstock is $.035/cubic metre and remains fixed through 1988. By 2002, costs rise to 65 percent of the projected Alberta Border Price (ABP). Values between 1988 and 2002 are linearly interpolated. The projected ABP is equal to 55 percent of the price of imported crude, delivered in Toronto, on an energy equivalent basis.

5. Methanol requirements in excess of 200,000 cubic metres per year are obtained by reducing methanol exports. All displaced exports would have been destined for U.S. Gulf Coast markets via rail to Vancouver and barge to New Orleans.

6. The base case price for methanol exports at Vancouver is projected as follows: The 1983 Gulf Coast price is taken as $\$146.22/m^3$. Real prices are assumed to decline by 5 percent in 1984, 1985 and 1986, remain constant to 1990, and increase by 1 percent real thereafter. The export price is a netback price from the Gulf Coast (i.e., Gulf Coast price minus shipping from Vancouver to the Gulf Coast minus duty).

7. Methanol is pipelined via Interprovincial Pipeline Ltd. (IPL) from Edmonton to Southern Ontario. The tariff is held constant, in real terms, throughout the period at $10.86/cubic metre. This is based on the IPL tariff of about $7.25/cubic metre for natural gas liquids plus a premium of 50 percent to cover additional costs and the inconvenience of carrying methanol.

8. All Ontario refiners blend methanol fuel (conditional on blended fuel demand) except Petrosar which does not produce motor gasoline.

9. Domestic cosolvent available for blending is limited to 78,000 cubic metres until additional domestic capacity is brought on stream in 1986.[1] Cosolvent is imported from the U.S. until sufficient domestic capacity becomes available to displace imports in 1988. The average cost of domestic cosolvent delivered to refineries is held at $386.44/cubic metre throughout the period. The price of imported cosolvent is held at $455.00/cubic metre based on a U.S. price plus transportation.

10. Refineries have adequate flexibility to make necessary adjustments in the product slate.

11. Additional storage tanks to accommodate the methanol and cosolvent are put in place at the refineries. The individual tank size is 1136.6 cubic metres (250,000 gallons) and the unit cost is $187,500. For a one-to-one ratio, 22 tanks are required.

12. Gasoline and butane prices escalate at the same rate as world oil prices.

13. The butane price is set at 85 percent of the Toronto price of crude.

14. Oxygenate is assumed to make up 10 percent of the blend by volume, in a one-to-one ratio (i.e., 5 percent methanol and 5 percent cosolvent).

15. Methanol has a high vapor pressure and can cause vapor lock problems when blended with regular gasoline unless the gasoline stock is adjusted to reduce the vapor pressure. The usual adjustment is to reduce the amount of butane in the gasoline. For each cubic metre of oxygenate included in the blended fuel, butane is backed-out of the gasoline stock according to the following formula:[2]

$$X\,(VO-VP) + B\,(VB - VP) = 0;$$

where: X = volume of oxygenate added;
VO = oxygenate vapor pressure;
VP = pool vapor pressure specification;
VB = butane vapor pressure; and
B = change in butane volume.

Assuming X = 1.0 m^3, VO = 32.5, VP = 11, and VB = 51.6, then 0.53 m^3 of butane will have to be backed-out for each m^3 of oxygenate added.[3]

16. Crude oil savings are calculated as the volume of oxygenate added minus the volume of butane savings. No adjustment is made for refinery gain.

17. The net octane credit is calculated according to the following formula:

$$NOC = C_o\,(R_o - R_g + B_b\,(R_b - R_g));$$

where: NOC = net octane credit in ¢/octane litre;
C_o = incremental octane cost in ¢/octane litre;
R_o = R + M/2 value for oxygenate;
R_g = R + M/2 value for gasoline;
B_b = butane backout/litre oxygenate; and
R_b = R + M/2 value for butane.

The base case parameters assumed are as follows: C_o = 0.25¢, R_o = 106.3, R_g = 88, B_b = 0.53, and R_b = 92.8.

A cost per incremental octane litre of 0.25¢ is above the range of costs associated with higher severity catalytic reforming but below the range of costs associated with the addition of toluene or MTBE.[4]

18. A 10 percent social rate of discount is assumed.

A.2 Impact Case Descriptions

The assumptions in the impact scenarios are changed one at a time. In each case, all assumptions are identical to those in the base case except the assumption being changed. The following assumptions have been changed as indicated.

CASE I Social Discount Rate of 5 percent

CASE II Social Discount Rate of 15 percent

CASE III Higher Methanol Price

- Methanol price is flat in real terms from 1984-1990, then grows at 1.5 percent real per annum.

CASE IV Methanol Transport by Rail

- Methanol is transported from Edmonton to Sarnia by unit train rather than IPL. The cost by rail is assumed to be $33.29/cubic metre.[5]

CASE V No Increased Domestic Cosolvent Capacity

- Domestic cosolvent capacity is restricted to 78,000 m^3 per year and all requirements above that level are imported.

CASE VI 2:1 Methanol to Cosolvent Ratio

- 5 percent methanol and 2.5 percent cosolvent are added with the resulting oxygenate making up 7.5 percent of the blend by volume.

CASE VII Lower Crude Oil Prices

- Crude oil prices are assumed to be 10 percent lower than the base case throughout the period.

CASE VIII Lower Butane Prices

- The butane price is assumed to be equal to 75 percent of the Toronto crude oil price.

CASE IX Higher Natural Gas Feedstock Costs

- Natural gas feedstock costs are assumed to be 50 percent higher throughout the period.

Footnotes

[1]See a study prepared for Celanese Canada, Ontario Ministry of Energy, and Energy, Mines and Resources Canada by Kilborn Kellog Rust, "Study of Cosolvent Supply for Gasoline Blending," May 1984.

[2]The formula is taken from James M. DeJovine et al., "Gasolines Show Varied Responses to Alcohols," Oil and Gas Journal, February 14, 1983.

[3]The Reid Vapor Pressure value of 32.5 is for a one-to-one blend of methanol to TBA and is found in Kenneth M. Stern, "Methanol Valuation in Gasoline Blends," Paper presented to the Third Annual Conference on the Alcohol Alternative, Chicago, May 1982.

[4]See, for example, two papers by Kenneth M. Stern, "Aspects of Methanol as a Transportation Fuel," presented at the Corpus Conference on Energy Pricing: The New Economies, October 27, 1981; and "Methanol Valuation in Gasoline Blends," presented at the Third Annual Conference on the Alcohol Alternative, Chicago, May 15, 1982. This assumption is also consistent with data presented by Ray Davies in an oral presentation at a CERI organized seminar "Methanol as an Automotive Fuel," Edmonton, June 18, 1984. The cost per incremental octane litre will vary significantly from one refinery to the next as indicated in M. M. Turner and R. E. Cunningham, "Fuel Methanol Markets: Refiners' and Blenders' Economics." Turner, Mason and Associates, Consulting Engineers, May 10, 1983.

[5]See a study prepared for Transport Canada by Hoe Middleton Partners, "Investigation of the Potential Use of Alcohol Fuels as Components of Transportation Fuel Supply," Ottawa, March 1983.

APPENDIX B

DETAILED BASE CASE DATA TABLES

YEAR	MOTOR GAS RETAIL SALES ONT (M3)	MOTOR GAS RETAIL SALES $ ONT (M3)	SHARE UNLEADED $ ONT	MOTOR GAS UNLEADED SALES $ ONT (M3)	SHARE BLENDED FUEL	BLENDED FUEL SALES $ ONT (M3)
1983	8730240.00	6547680.00	0.40	2619072.00	0.40	1047628.80
1984	8730240.00	6547680.00	0.45	2946456.00	0.60	1767873.60
1985	8730240.00	6547680.00	0.50	3273840.00	0.80	2619072.00
1986	8730240.00	6547680.00	0.55	3601224.00	1.00	3601224.00
1987	8730240.00	6547680.00	0.60	3928608.00	1.00	3928608.00
1988	8730240.00	6547680.00	0.65	4255992.00	1.00	4255992.00
1989	8730240.00	6547680.00	0.70	4583376.00	1.00	4583376.00
1990	8730240.00	6547680.00	0.75	4910760.00	1.00	4910760.00
1991	8730240.00	6547680.00	0.80	5238144.00	1.00	5238144.00
1992	8730240.00	6547680.00	0.85	5565528.00	1.00	5565528.00
1993	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
1994	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
1995	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
1996	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
1997	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
1998	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
1999	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
2000	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
2001	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00
2002	8730240.00	6547680.00	0.90	5892912.00	1.00	5892912.00

YEAR	QUANTITY CRUDE DISPLACED (M3)	PRICE OF IMPORTED CRUDE, LANDED MONTREAL (1983$/M3)	TRANSPORT COST_OIL MNT_SARNIA (1983$/M3)	B1 BENEFIT OF DISPLACED CRUDE (1983$)
1983	49238.55	234.37	1.12	11595138.40
1984	83090.06	224.13	1.12	18716275.68
1985	123096.38	223.16	1.12	27608450.54
1986	169257.53	223.16	1.12	37961569.15
1987	184644.58	223.16	1.12	41412611.38
1988	200031.62	223.16	1.12	44863681.95
1989	215418.67	223.16	1.12	48314724.34
1990	230805.72	225.20	1.12	52236004.81
1991	246192.77	227.26	1.12	56225065.32
1992	261579.82	229.34	1.12	60282819.71
1993	276966.86	231.44	1.12	64410286.25
1994	276966.86	233.56	1.12	64997577.33
1995	276966.86	235.70	1.12	65590673.67
1996	276966.86	237.86	1.12	66189690.53
1997	276966.86	240.04	1.12	66794671.96
1998	276966.86	242.25	1.12	67405818.26
1999	276966.86	244.48	1.12	68023013.21
2000	276966.86	246.73	1.12	68646310.87
2001	276966.86	249.00	1.12	69275931.42
2002	276966.86	251.30	1.12	69911830.80

YEAR	QUANTITY CRUDE DISPLACED (M3)	REFINING COST,CRUDE TO MOTOR GASOLINE (1983$/M3)	B2 , BENEFIT OF REDUCED REFINERY THROUGHPUT (1983$)
1983	49238.55	25.16	1238804.59
1984	83090.06	25.16	2090482.74
1985	123096.38	25.16	3097011.47
1986	169257.53	25.16	4258390.77
1987	184644.58	25.16	4645517.20
1988	200031.62	25.16	5032643.64
1989	215418.67	25.16	5419770.07
1990	230805.72	25.16	5806896.50
1991	246192.77	25.16	6194022.94
1992	261579.82	25.16	6581149.37
1993	276966.86	25.16	6968275.80
1994	276966.86	25.16	6968275.80
1995	276966.86	25.16	6968275.80
1996	276966.86	25.16	6968275.80
1997	276966.86	25.16	6968275.80
1998	276966.86	25.16	6968275.80
1999	276966.86	25.16	6968275.80
2000	276966.86	25.16	6968275.80
2001	276966.86	25.16	6968275.80
2002	276966.86	25.16	6968275.80

YEAR	QUANTITY OF OXYGENATE (M3)	NET OCTANE CREDIT (1983$/M3)	23 BENEFIT OF OCTANE ENHANCEMEN (1983$)
1983	104762.88	39.39	4126609.84
1984	176787.36	39.39	6963654.11
1985	261907.20	39.39	10316524.61
1986	360122.40	39.39	14185221.34
1987	392860.80	39.39	15474786.91
1988	425599.20	39.39	16764352.49
1989	458337.60	39.39	18053918.06
1990	491076.00	39.39	19343483.64
1991	523814.40	39.39	20633049.22
1992	556552.80	39.39	21922614.79
1993	589291.20	39.39	23212180.37
1994	589291.20	39.39	23212180.37
1995	589291.20	39.39	23212180.37
1996	589291.20	39.39	23212180.37
1997	589291.20	39.39	23212180.37
1998	589291.20	39.39	23212180.37
1999	589291.20	39.39	23212180.37
2000	589291.20	39.39	23212180.37
2001	589291.20	39.39	23212180.37
2002	589291.20	39.39	23212180.37

YEAR	QUANTI:: OF BUTANE BACKED OUT (M3)	PRICE OF BUTANE (1983$/M3)	24 BENEFIT OF ADDITIONAL BUTANE (1983$)
1983	55524.33	200.17	11114063.51
1984	93697.30	191.46	17939749.35
1985	138810.82	190.64	26462993.55
1986	190864.87	190.64	36386567.87
1987	208216.22	190.64	39694428.56
1988	225567.58	190.64	43002316.42
1989	242918.93	190.64	46310177.27
1990	260270.28	192.37	50068766.32
1991	277621.63	194.12	53892323.25
1992	294972.98	195.89	57781724.00
1993	312324.34	197.67	61737944.59
1994	312324.34	199.47	62300869.33
1995	312324.34	201.30	62869358.49
1996	312324.34	203.13	63443522.52
1997	312324.34	204.99	64023403.65
1998	312324.34	206.87	64609193.89
1999	312324.34	208.76	65200781.81
2000	312324.34	210.67	65798219.24
2001	312324.34	212.61	66401717.25
2002	312324.34	214.56	67011241.23

YEAR	QUANTITY COSOLVENT IMPORTED (M3)	COSOLVENT COST IMPORTED (1983$/M3)	TOTAL COST OF COSOLVENT IMPORTS (1983$)	QUANTITY OF CORROSION INHIBITORS, IMPORTED (LBS)	CORROSION INHIBITOR COST, IMPORTED (1983$/LB)	TOTAL COST OF CORROSION INHIBITORS, IMPORTED (1983$)	LESS COST OF TOTAL IMPORTS (1983$)
1983	0.00	455.00	0.00	13837.72	2.40	33210.52	33210.52
1984	10319.04	455.00	4695162.84	23351.15	2.40	56042.75	4751205.58
1985	52878.96	455.00	24059926.44	34594.29	2.40	83026.29	24142952.73
1986	30061.20	455.00	13677846.00	47567.15	2.40	114161.15	13792007.15
1987	11430.40	455.00	5200832.00	51891.43	2.40	124539.44	5325371.44
1988	0.00	455.00	0.00	56215.72	2.40	134917.73	134917.73
1989	0.00	455.00	0.00	60540.01	2.40	145296.01	145296.01
1990	0.00	455.00	0.00	64864.29	2.40	155674.30	155674.30
1991	0.00	455.00	0.00	69188.58	2.40	166052.59	166052.59
1992	0.00	455.00	0.00	73512.86	2.40	176430.87	176430.87
1993	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
1994	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
1995	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
1996	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
1997	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
1998	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
1999	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
2000	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
2001	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16
2002	0.00	455.00	0.00	77837.15	2.40	186809.16	186809.16

YEAR	QUANTITY OF DISPLACED METHANOL EXPORTS (M3)	PRICE OF DISPLACED METHANOL EXPORTS (FOB CDN BORDER) (1983$/M3)	LESS LOST METHANOL EXPORT REVENUE (1983$)
1983	0.00	132.04	0.00
1984	0.00	124.18	0.00
1985	0.00	115.58	0.00
1986	0.00	107.41	0.00
1987	0.00	107.41	0.00
1988	12799.60	107.41	1374849.07
1989	29168.80	107.41	3133121.15
1990	45538.00	107.41	4891393.23
1991	61907.20	108.97	6745761.38
1992	78276.40	110.53	8652163.10
1993	94645.60	112.12	10611375.34
1994	94645.60	113.72	10762741.58
1995	94645.60	115.33	10915621.48
1996	94645.60	116.96	11070030.18
1997	94645.60	118.61	11225982.97
1998	94645.60	120.27	11383495.28
1999	94645.60	121.96	11542582.72
2000	94645.60	123.65	11703261.03
2001	94645.60	125.37	11865546.12
2002	94645.60	127.10	12029454.07

YEAR	INCREMENTAL METHANOL PRODUCTION (M3)	QUANTITY NAT. GAS FEEDSTOCK (M3)	NAT. GAS FEEDSTOCK COST (1983$/M3)	£1 TOTAL COST OF FEEDSTOCK, INCREMENTA PRODUCTION (1983$)
1983	52381.44	47541695.41	0.04	1678267.58
1984	88393.68	80226611.00	0.04	2832076.55
1985	130953.60	118854238.52	0.04	4195668.96
1986	180061.20	163424577.96	0.04	5769044.82
1987	196430.40	178281357.78	0.04	6293503.44
1988	200000.00	181521147.21	0.04	7036330.37
1989	200000.00	181521147.21	0.04	7664789.63
1990	200000.00	181521147.21	0.05	8293248.88
1991	200000.00	181521147.21	0.05	8921708.13
1992	200000.00	181521147.21	0.05	9550167.38
1993	200000.00	181521147.21	0.06	10178626.64
1994	200000.00	181521147.21	0.06	10807085.89
1995	200000.00	181521147.21	0.06	11435545.14
1996	200000.00	181521147.21	0.07	12064004.40
1997	200000.00	181521147.21	0.07	12692463.65
1998	200000.00	181521147.21	0.07	13320922.90
1999	200000.00	181521147.21	0.08	13949382.16
2000	200000.00	181521147.21	0.08	14577841.41
2001	200000.00	181521147.21	0.08	15206300.66
2002	200000.00	181521147.21	0.09	15834759.91

YEAR	INCREMENTAL METHANOL PRODUCTION (M3)	UNIT OPERATING COSTS FOR INCREMENTAL PRODUCTION (1983$)	£2 TOTAL OPERATING COSTS FOR INCREMENTA PRODUCTION (1983$)
1983	52381.44	16.30	853817.47
1984	88393.68	16.30	1440816.98
1985	130953.60	16.30	2134543.68
1986	180061.20	16.30	2934997.56
1987	196430.40	16.30	3201815.52
1988	200000.00	16.30	3260000.00
1989	200000.00	16.30	3260000.00
1990	200000.00	16.30	3260000.00
1991	200000.00	16.30	3260000.00
1992	200000.00	16.30	3260000.00
1993	200000.00	16.30	3260000.00
1994	200000.00	16.30	3260000.00
1995	200000.00	16.30	3260000.00
1996	200000.00	16.30	3260000.00
1997	200000.00	16.30	3260000.00
1998	200000.00	16.30	3260000.00
1999	200000.00	16.30	3260000.00
2000	200000.00	16.30	3260000.00
2001	200000.00	16.30	3260000.00
2002	200000.00	16.30	3260000.00

YEAR	TOTAL QUANTITY METHANOL (M3)	METHANOL PIPELINE TARIFF ALTA_SARNIA (1983$/M3)	£3 TOTAL METHANOL PIPELINE COSTS (1983$)
1983	52381.44	10.86	568862.44
1984	88393.68	10.86	959955.36
1985	130953.60	10.86	1422156.10
1986	180061.20	10.86	1955464.63
1987	196430.40	10.86	2133234.14
1988	212799.60	10.86	2311003.66
1989	229168.80	10.86	2488773.17
1990	245538.00	10.86	2666542.68
1991	261907.20	10.86	2844312.19
1992	278276.40	10.86	3022081.70
1993	294645.60	10.86	3199851.22
1994	294645.60	10.86	3199851.22
1995	294645.60	10.86	3199851.22
1996	294645.60	10.86	3199851.22
1997	294645.60	10.86	3199851.22
1998	294645.60	10.86	3199851.22
1999	294645.60	10.86	3199851.22
2000	294645.60	10.86	3199851.22
2001	294645.60	10.86	3199851.22
2002	294645.60	10.86	3199851.22

YEAR	QUANTITY COSOLVENT DOMESTIC (M3)	COSOLVENT COST, DOMESTIC (1983$/M3)	C4 TOTAL DOMESTIC COSOLVENT COSTS (1983$)
1983	52381.44	386.44	20242283.67
1984	78074.64	386.44	30171164.19
1985	78074.64	386.44	30171164.19
1986	150000.00	386.44	57966000.00
1987	185000.00	386.44	71491400.00
1988	212799.60	386.44	82234277.42
1989	229168.80	386.44	88559991.07
1990	245538.00	386.44	94885704.72
1991	261907.20	386.44	101211418.37
1992	278276.40	386.44	107537132.02
1993	294645.60	386.44	113862845.66
1994	294645.60	386.44	113862845.66
1995	294645.60	386.44	113862845.66
1996	294645.60	386.44	113862845.66
1997	294645.60	386.44	113862845.66
1998	294645.60	386.44	113862845.66
1999	294645.60	386.44	113862845.66
2000	294645.60	386.44	113862845.66
2001	294645.60	386.44	113862845.66
2002	294645.60	386.44	113862845.66

YEAR	NO OF ADDITIONAL STORAGE TANKS METHANOL CAP 1140M3 (NUMBER)	NO OF ADDITIONAL STORAGE TANKS COSOLVENT CAP 1140M3 (NUMBER)	UNIT COST PER TANK (1983$)	C5 COST OF ADDITIONAL STORAGE AT REFINERS (1983$)
1983	5.00	5.00	187500.00	1875000.00
1984	1.00	1.00	187500.00	375000.00
1985	1.00	1.00	187500.00	375000.00
1986	1.00	1.00	187500.00	375000.00
1987	1.00	1.00	187500.00	375000.00
1988	1.00	1.00	187500.00	375000.00
1989	1.00	1.00	187500.00	375000.00
1990	0.00	0.00	187500.00	0.00
1991	0.00	0.00	187500.00	0.00
1992	0.00	0.00	187500.00	0.00
1993	0.00	0.00	187500.00	0.00
1994	0.00	0.00	187500.00	0.00
1995	0.00	0.00	187500.00	0.00
1996	0.00	0.00	187500.00	0.00
1997	0.00	0.00	187500.00	0.00
1998	0.00	0.00	187500.00	0.00
1999	0.00	0.00	187500.00	0.00
2000	0.00	0.00	187500.00	0.00
2001	0.00	0.00	187500.00	0.00
2002	0.00	0.00	187500.00	0.00

YEAR	QUANTITY OF DISPLACED METHANOL EXPORTS (M3)	TRANSPORT, ALTA TO CANADIAN BORDER (1983$/M3)	LESS TOTAL TRANSPORT COSTS (DISPLACED METH EXP) (1983$)
1983	0.00	26.97	0.00
1984	0.00	26.97	0.00
1985	0.00	26.97	0.00
1986	0.00	26.97	0.00
1987	0.00	26.97	0.00
1988	12799.60	26.97	345196.50
1989	29168.80	26.97	786662.69
1990	45538.00	26.97	1228128.87
1991	61907.20	26.97	1669595.05
1992	78276.40	26.97	2111061.24
1993	94645.60	26.97	2552527.42
1994	94645.60	26.97	2552527.42
1995	94645.60	26.97	2552527.42
1996	94645.60	26.97	2552527.42
1997	94645.60	26.97	2552527.42
1998	94645.60	26.97	2552527.42
1999	94645.60	26.97	2552527.42
2000	94645.60	26.97	2552527.42
2001	94645.60	26.97	2552527.42
2002	94645.60	26.97	2552527.42

APPENDIX C

SOCIAL BENEFIT-COST ANALYSIS
SUMMARY OF RESULTS

TABLE C.1

SOCIAL BENEFIT-COST ANALYSIS OF BLENDING METHANOL WITH GASOLINE IN SOUTHERN ONTARIO
(million discounted $1983)

	Base Case	5 % Disc. Rate	15 % Disc. Rate	High Meth. Price	Meth. By Rail	High Cosol. Cost	2:1 Meth. Cosol.	Low Oil Price	Low Butane Price	High Gas Cost
Benefit-Cost Ratio	1.14	1.14	1.14	1.13	1.08	1.10	1.47	1.04	1.08	1.05
Net Present Value	115	178	79	104	72	38	223	36	68	80
Discounted Net Benefits										
Displaced Imported Crude Oil	416	639	291	416	416	416	199	374	416	416
Reduced Refinery Throughput	45	69	32	45	45	45	22	45	45	45
Net Octane Credit	150	229	106	150	150	150	128	150	150	150
Butane Savings	398	613	278	398	398	398	395	358	351	398
Less: Imports	(39)	(44)	(35)	(39)	(39)	(547)	(1)	(39)	(39)	(39)
Less: Lost Export Revenue	(41)	(73)	(24)	(51)	(41)	(41)	(41)	(41)	(41)	(41)
Total Discounted Net Benefits	929	1 433	647	918	929	421	700	847	882	929
Discounted Net Costs										
Feedstock Costs	70	111	48	70	70	70	70	68	70	105
Operating Costs	25	37	18	25	25	25	25	25	25	25
Pipeline Costs	21	32	15	21	63	21	21	21	21	21
Domestic Cosolvents	704	1 088	489	704	704	273	368	704	704	704
Storage Tanks	4	4	3	4	4	4	3	4	4	4
Less: Transport Cost Savings	(10)	(17)	(6)	(10)	(10)	(10)	(10)	(10)	(10)	(10)
Total Discounted Net Costs	814	1 255	568	814	857	383	478	812	814	884

APPENDIX D

SUMMARY OF SELECTED METHANOL BLENDING TEST RESULTS

Appendix D

SUMMARY OF SELECTED METHANOL BLENDING TEST RESULTS

Oxygenated Fuels Technical Bulletin, No. 8301 - January 1983
Arco Chemical Co. Pennsylvania

"Oxinal 50 Blending Component Market Test Customer Survey Results."

- 1982 test one-to-one methanol/TBA in 9-9.4 volume percent blend,
- excellent customer satisfaction,
- no special equipment in cars,
- sample size approximately 300,
- three samples taken: January (pre-test), March, August,
- samples also taken in a nearby control market not using oxinol,
- no significant change in levels of customer satisfaction in test market, or in test market relative to control market.

Evaluation of Methanol/Isobutanol Gasoline Blend Under Canadian Driving Conditions, Ontario Research Foundation, Engineering Sciences Division, Centre for Alternative Fuels Utilization, Mississauga, Ontario, April 1984.

- study done for Celanese Canada Inc.,
- 4.75 percent methanol/4.75 percent isobutanol (blend similar to Oxinol 50,
- one year test (1982),
- 2 fleets, 22 taxis and 12 Celanese company cars,
- 1,000,000 km,
- drivers could find no difference between blend and unleaded regular,
- no change in fuel consumption for blend vs. regular gasoline
- no cold weather starting/driveability problems at -36°C,
- no change in wear of engines, carburetors, fuel pumps, fuel tanks, or exhaust catalysts that could be attributed to methanol,
- emissions of carbon monoxide and hydrocarbons lower with blend,
- emissions of nitrogen oxides higher,
- no evidence of phase separation--samples taken at refinery, delivery tanker, and service station tanks on a weekly basis for water and monthly for alcohol analysis,
- fuel consumption: with blend: 19.3 L/100 km.
  unleaded regular: 18.9 L/100 km.

"Methanol/Gasoline Blend Vehicle Fleet Demonstration," K. Taylor (MTC) paper presented to VI International Symposium on Alcohol Fuels Technology, Ottawa, May 1984.

- joint project of Alberta Gas Chemicals Ltd; Ontario Ministry of Transportation and Communications; Suncor Sunoco Group.
- 7 percent methanol/3 percent cosolvent,
- 34 vehicle fleet,
- tested for fuel consumption, emissions, equivalence ratios,
- fuel handling equipment tested for wear,
- no significant problems found for wear or driveability,
- no phase separation,
- no wear on pump,
- no driveability problems except during early warm-up from cold start,
- no change in wear patterns or spent lubricant characteristics,
- no significant increase in fuel consumption,
- carbon monoxide emissions down, no clear trend in hydrocarbon emissions or nitrogen oxide emissions,
- no cross-fueling problems.

"Operating Experience of a Baltimore, Maryland/USA Fleet Using a 90/10 Blend of Methanol/Unleaded Gasoline." R. L. Bechtold et al., VI International Symposium on Alcohol Fuels Technology, Ottawa, May 1984.

- ninety-to-ten unleaded gasoline-to-methanol,
- 6 test vehicles, 6 control vehicles,
- no fuel economy difference,
- better driveability with methanol,
- no data on engine wear,
- vehicles modified for blend,
- carburetor modified, fuel tank coated, spark retard slowed,
- dedicated storage,
- pump wore out (on distribution tank).

BIBLIOGRAPHY

Bechtold, R. L. "Operating Experience of a Baltimore, Maryland/USA Fleet Using a 90/10 Blend of Methanol/Unleaded Gasoline." Paper presented at the VIth International Symposium on Alcohol Fuels Technology, Ottawa, May 1984.

Canadian Oxygenated Fuels Association. "Methanol as a Transportation Fuel." Paper presented at the Canadian Energy Research Institute Seminar, "Methanol as an Automative Fuel," Edmonton, June 18, 1984.

Celanese Canada, Ontario Ministry of Energy, and Energy, Mines and Resources Canada. "Study of Cosolvent Supply for Gasoline Blending." Study prepared by Kilborn Kellog Rust, May 1984.

College, R. "The Methanol Fuel Alternative." Presentation to Ontario Ministry of Transportation and Communication, Toronto, Ontario, February 15, 1983.

Davies, Ray. Oral presentation at the Canadian Energy Research Institute Seminar, "Methanol as an Automotive Fuel," Edmonton, June 18, 1984.

DeJovine, James M. et al. "Gasolines Show Varied Responses to Alcohols." Oil and Gas Journal, February 14, 1983.

Haessel, W. "Results of Recent CERI Benefit/Cost Study: An Overview." Paper presented at the Canadian Energy Research Institute Seminar, "Methanol as an Automotive Fuel," Edmonton, June 18, 1984.

Haessel, W., and Gibson T. "A Social Benefit-Cost Analysis of Using Methanol as a Motor Gasoline Extender in Southern Ontario," in VI International Symposium on Alcohol Fuels Technology Proceedings. Volume II. Ottawa; May 1984.

Lambie, J. K. "Developments in Methanol and its Derivatives and Their Impact on the Western Canadian Natural Gas Industry." Paper presented to the Canadian Gas Processors Association, Calgary, September 12, 1984.

McDill, D., Messenger, G., and Moon, G. Field and Laboratory Evaluation of the Use of Methanol-Gasoline Mixtures as Motor Fuel. National Research Council Canada, LTR-FL-201, January 23, 1981.

Ontario Research Foundation, Engineering Sciences Division, Centre for Alternative Fuels Utilization. Evaluation of Methanol/ Isobutanol Gasoline Blend Under Canadian Driving Conditions. Mississauga, Ontario: Ontario Research Foundation, April 1984.

Oxygenated Fuels Technical Bulletin, No. 8301, January 1983. "Oxinal 50 Blending Component Market Test Customer Survey Results." Pennsylvania: Arco Chemical Co., January 1983.

Stern, Kenneth M. "Aspects of Methanol as a Transportation Fuel." Paper presented at the Corpus Conference on Energy Pricing: The New Economies, October 27, 1981.

Stern, Kenneth M. "Methanol Valuation in Gasoline Blends." Presentation to the Third Annual Conference on the Alcohol Alternative, Chicago, May 5, 1982.

Taylor, K. (MTC). "Methanol/Gasoline Blend Vehicle Fleet Demonstration." Paper presented at the VIth International Symposium on Alcohol Fuels Technology, Ottawa, May 1984.

Transport Canada. "Investigation of the Potential Use of Alcohol Fuels as Components of Transportation Fuel Supply." Prepared by Hoe Middleton Partners. Ottawa, March 1983.

Turner, M. M., and Cunningham, R. E. "Fuel Methanol Markets: Refiners' and Blenders' Economics." Turner, Mason and Associates, Consulting Engineers, May 10, 1983.

CANADIAN ENERGY RESEARCH INSTITUTE

PUBLICATIONS

Studies

No. 1 The Availability of Capital to Fund the Development of Canadian Energy Supplies. J. R. Downs. November 1977 (Price $3.00, 109 Pages) ISBN 0-920522-00-9.

No. 2 The Industrial Demand for Oil and Gas in Ontario. DataMetrics Limited. March 1978 (Price $3.00, 119 pages) ISBN 0-920522-01-7.

No. 3 The Effects of Rising Energy Costs on Canadian Industry. Anthony P. Ellison. April 1979 (Price $3.00, 62 pages) ISBN 0-920522-02-5.

No. 4 Potential Markets for Thermal Coal in Canada, 1978-2000: Summary and Conclusions. Canadian Resourcecon Limited. June 1979 (Price $3.00, 27 pages) ISBN 0-920522-03-3.

No. 5 Energy in Canada: Review and Outlook to 1995. W. Brent Friedenberg. July 1979 (Price $10.00, 140 pages) ISBN 0-920522-04-1.

No. 6 Energy Policy and the Balance of Payments: An Outline of the Issues. T. L. Powrie. July 1979 (Price $3.00, 61 pages) ISBN 0-920522-05-X.

No. 7 Oil and Gas Finding Costs. Russell S. Uhler. September 1979 (Price $3.00, 75 pages) ISBN 0-920522-06-8.

No. 8 Energy Use in Canada in Comparison with Other Countries. Z. Charles Slagorsky. October 1979 (Price $3.00, 91 pages) ISBN 0-920522-07-6.

No. 9 Enhanced Oil Recovery Potential in Canada. J. Philip Prince. March 1980 (Price $10.00, 332 pages) ISBN 0-920522-09-2.

Conclusions and Policy Implications from Enhanced Oil Recovery Potential in Canada, Study No. 9. J. Philip Prince. March 1980 (Price $3.00, 32 pages) ISBN 0-920522-10-6.

No. 10 The Impact of Rate Structure Change on Electricity Demand: A Case Study of Calgary Power Limited. Gerard J. Protti and Robert N. McRae. April 1980 (Price $10.00, 182 pages) ISBN 0-920522-11-4.

Overview and Summary from the Impact of Rate Structure Change on Electricity Demand: A Case Study of Calgary Power Limited. Gerard J. Protti and Robert N. McRae. April 1980 (Price $3.00, 14 pages) ISBN 0-920522-12-2.

No. 11 The Impact of a Sharp Oil Price Increase. G. E. Angevine. June 1980 (Price $10.00, 122 pages) ISBN 0-920522-13-0.

No. 12 Benefits and Costs of Oil Self-Sufficiency in Canada. J. A. Dawson and Z. C. Slagorsky. February 1981 (Price $10.00, 97 pages) ISBN 0-920522-15-7.

No. 13 Financing Canadian Energy Resource Development. J. A. Dawson. December 1981 (Price $10.00, 68 pages) ISBN 0-920522-17-3.

No. 14 Impacts of Canada's Uranium Mining Industry. Marvin Shaffer and Associates Ltd. May 1982 (Price $10.00, 87 pages) ISBN 0-920522-20-3.

No. 15 Coal and Nuclear Electricity Fuels: A Regional Analysis. Farhood Rahnama. June 1982 (Price $10.00, 80 pages) ISBN 0-920522-21-1.

No. 16 Alternative Transportation Fuels in Canada. Z. Charles Slagorsky. July 1982 (Price $10.00, 112 pages) ISBN 0-920522-23-8.

No. 17 Energy and Regional Investment in Canada. Gordon W. Douglas and Ellen F. Battle. March 1983 (Price $20.00, 114 pages) ISBN 0-920522-28-9.

No. 18 Household Energy Savings: Options for the Future. Brian D. Sumner and Barbara E. Green. March 1983 (Price $20.00, 194 pages) ISBN 0-920522-27-0.

No. 19 Modelling Exploration Success in Alberta Oil Plays. Kenneth D. Foat and Alan J. MacFadyen. September 1983 (Price $15.00, 181 pages) ISBN 0-920522-29-7.

No. 20 The Oil and Gas Investment Climate: Changes Over a Decade. DataMetrics Limited. June 1984 (Price $15.00, 76 pages) ISBN 0-920522-31-9.

Appendix Volume to Study No. 20. The Oil and Gas Investment Climate: Changes Over a Decade. DataMetrics Limited. June 1984 (Price $12.00, 141 pages).

Client Research Reports

81-1 Models for Energy Policy Analysis: A Survey. Kenneth D. Foat, Gerard J. Protti and Gordon W. Douglas. July 1981 (Price $10.00, 121 pages) ISBN 0-920522-16-5.

82-1 The Economics of Improved Energy Efficiency in New Calgary Housing. Barbara E. Green. March 1982 (Price $10.00, 55 pages) ISBN 0-920522-18-1.

82-2 Interregional Economic Impacts of the Alberta Alsands Project. Gordon W. Douglas and J. A. MacMillan. September 1982 (Price $15.00, 78 pages) ISBN 0-920522-24-6.

83-1 Potential Benefits and Costs of Canadian Electricity Exports. Ellen F. Battle, Gordon S. Gislason and Gordon W. Douglas. April 1983 (Price $25.00, 288 pages) ISBN 0-920522-26-2.

Working Papers

78-1 Drilling and Field Construction Costs in the Canadian Petroleum Industry. Gordon M. Engbloom, Confer Consulting Limited. January 1978 (Price $3.00, 83 pages).

78-2 Some Supply Price Estimates for Synthetic Crude Oil in Canada. Z. Charles Slagorsky. April 1978 (Price $3.00, 42 pages).

78-3 Past and Future Energy Costs in the Canadian Economy. Anthony P. Ellison. April 1978 (Price $5.00, 136 pages).

78-4 Canadian Electric Utility Industry Costs, 1960-1990. Gerard J. Protti. May 1978 (Price $10.00, 218 pages).

78-5 Enhanced Oil Recovery Potential in Canada--A Methodological Preview. J. Philip Prince. June 1978 (Price $10.00, 184 pages).

78-6 Regional Energy and Production Data for Canadian Manufacturing Industries: 1962-74. Robert N. McRae and Alan R. Webster. July 1978 (Price $5.00, 106 pages).

78-7 Regional Demand for Energy by Canadian Manufacturing Industries. Robert N. McRae. October 1978 (Price $5.00, 132 pages).

79-1 An Input-Output Analysis of the Effects of Rising Energy Costs on Canadian Industries. Anthony P. Ellison. April 1979 (Price $10.00, 246 pages).

79-2 Potential Markets for Thermal Coal in Canada, 1978-2000. Canadian Resourcecon Limited. June 1979 (Price $15.00, 321 pages).

79-3 Inter-City Comparisons of Canadian Household Energy Costs. Darcy-Gail Ackerman. June 1979 (Price $3.00, 77 pages).

80-1 Government Incentives in Canada's Petroleum Industry. W. B. Friedenberg, Z. C. Slagorsky, and A. J. Walsh. March 1980 (Price $3.00, 43 pages).

80-2 A Regionalized Electricity Model: Preliminary Analyses. Kenneth D. Foat and Gerard J. Protti. April 1980 (Price $3.00, 61 pages).

80-3 Alternative Future Supplies of Oil in Canada and their Costs. Z. Charles Slagorsky. May 1980 (Price $3.00, 36 pages).

80-4 Prospects for Reduced Oil Consumption in Canada. W. B. Friedenberg and A. J. Nixon. May 1980 (Price $3.00, 34 pages).

81-1 Crude Oil Supply and Demand: Major Issues and Alternate Scenarios. Douglas J. Haughey. July 1981 (Price $7.00, 158 pages).

81-2 Natural Gas Pricing in Canada: An Economic Analysis. Andrea J. Nixon. October 1981 (Price $5.00, 116 pages).

82-1 Potential for Reducing Oil Demand through Conservation. Georgette Habib. September 1982 (Price $7.00, 47 pages).

83-1 Development Options for Maritime Coal. John A. Dawson. January 1983 (Price $7.50, 42 pages).

83-2 Development Options for Alberta and Saskatchewan Coal. Tricia Gibson. March 1983 (Price $7.50, 44 pages).

83-3 Development Options for British Columbia Coal. Kristi E. Varangu. April 1983 (Price $7.50, 107 pages).

83-4 The Impacts of Crude Oil Supply Changes and Supply Allocation. Douglas J. Haughey and Donald A. Bruton. May 1983 (Price $7.50, 72 pages).

83-6 The Potential for Energy Substitution in Canada. Brian D. Sumner. September 1983 (Price $7.50, 124 pages).

84-1 A Review of Oil and Gas Drilling Activity Forecasting Techniques. G. E. Angevine, S. R. Cain and Z. C. Slagorsky. March 1984 (Price $5.00, 20 pages).

84-2 An Assessment of Benefits and Costs of Using Methanol as a Motor Gasoline Extender in Southern Ontario. Walter Haessel and Tricia Gibson. September 1984 (Price $10.00, 62 pages).

Discussion Papers

82-1 Significance of Interregional Feedbacks for Canadian and Regional Energy Policy Decisions. Gordon W. Douglas and James A. MacMillan. March 1982 (Price $2.00, 10 pages).

83-1 The Alberta New Oil Royalty Formula: 74-04-01 to 82-12-31. Alan R. Webster. March 1983 (Price $6.00, 56 pages).

Presentations by Staff (available upon request)

83-1 Household Energy Costs: Recent Developments and Options for the Future. G. E. Angevine. Notes for Remarks at the "New Neighbourhood Forum," sponsored by the Ontario Ministry of Housing and Municipal Affairs, Toronto, January 31, 1983.

83-2 Net Regional and National Benefits of Canadian Electricity Exports. Gordon S. Gislason, Ellen F. Battle, and Gordon W. Douglas. Paper presented to the Canadian Electrical Association Generation System Planning and Operation Subsection, Vancouver, March 21, 1983.

83-3 Economic and Financial Implications of Lower Oil Prices. Walter Haessel. Paper presented at a conference on The Impact of Lower Oil Prices, sponsored by Data Resources of Canada, Sheraton Centre, Toronto, April 14, 1983

83-4 Energy Pricing in the World and Canada. James A. MacMillan. Paper presented to the Canadian Chapter of the International Association of Energy Economists, Toronto, May 20, 1983

83-5 Canadian Energy Issues and Outlook. Douglas J. Haughey. Paper presented to the Institute of Internal Auditors, Calgary, October 18, 1983.

84-1 The CANREM Model: Model Structure, User Experience and Potential Applications. Gordon W. Douglas, Gordon S. Gislason and Ellen F. Battle. Presentation to the Canadian Electrical Association Meetings, Edmonton, March 15, 1984.

Proceedings

Markets for Canadian Uranium. Proceedings of a Seminar held on October 25, 1979, Calgary, Alberta (Price $10.00, 89 pages) ISBN 0-920522-08-4.

Economic Potential for Alternative Transportation Fuels: Methanol, Ethanol, Propane, Liquified Coal, Compressed Natural Gas and Hydrogen. Proceedings of a Seminar held on November 17, 1981, Calgary, Alberta. (Price $10.00, 83 pages) ISBN 0-920522-19-X.

World Oil Market Conference. Proceedings of a Conference held on October 18, 1982, Calgary, Alberta. Edited by Shane S. Streifel (Price $50.00, 220 pages) ISBN 0-920522-25-4.

International Gas Markets Conference. Proceedings of a Conference held on September 26, 1983, Calgary, Alberta. Edited by Shane Streifel. (Price $45.00, 247 pages) ISBN 0-920522-33-5.

Annual Report

Board of Directors' Report for the Year Ended March 31, 1984. ISBN 0-920522-32-7.